

THREE-DIMENSIONAL INFORMATION MANAGEMENT FOR BURIED OBJECTS UNDER ROADS

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ABSTRACT

To promote innovation in civil infrastructure, three-dimensional models can be efficiently and smoothly used throughout the project lifecycle. In Japan, three-dimensional models are not often used in civil infrastructure projects. It is necessary to identify and define specific work procedures where utilizing three-dimensional models would be beneficial and clearly improve downstream processes.

This study targets local government maintenance of buried objects under roads as a use case for three-dimensional models. The soft systems methodology is adopted to analyze issues related to project participants and to design the system architecture. Issues related to the use of three-dimensional models include a lack of finance, human resource shortages, and a lack of understanding of the merits of analysis using rich pictures. CATWOE analysis describes the elements for constructing a three-dimensional management system. A system architecture of a management system for buried objects under roads is proposed that creates three-dimensional models, manages maintenance information, and can be used by road administrators and construction engineers. Designed system functions include visualization of the three-dimensional model, referencing, updates, and registration, as well as retrieval of the location and attitude of buried objects and a layer representation of each pipe. In the system, a data model for buried objects under roads is defined using UML (Unified Modeling Language). It includes information describing object location and depth, creation date, data creator, local government name, owning company, and geometry data for water, sewerage, and gas pipes and common ducts, communication and electricity pipes, and other underground structures. The proposed system has a data model framework capable of buried object maintenance and road asset management using three-dimensional models.

KEYWORDS: Road Maintenance, Buried Object, Three-Dimensional Model, Information Management System, Soft Systems Methodology

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INTRODUCTION

Background

To promote innovation in public works through the use of information and communication technology, an environment should be provided in which three-dimensional (3D) information on structures can be efficiently and smoothly used throughout the project lifecycle. At present, the use of electronic data in public works projects has not been optimized, and efforts have not been undertaken from the viewpoint of total optimization over the lifecycle of projects. It is therefore necessary to identify and define specific work procedures such as quantity calculations where utilizing 3D information is beneficial, and to specify uses resulting in clear downstream process improvements, such as data input into quantity calculation software. Furthermore, work processes must be

designed based on these uses, and, if necessary, systems should be created and exchange standards developed.

This study targets local government maintenance of buried objects under roads as a use case for 3D models. The soft systems methodology (SSM, Iwashita, 2014) was adopted to analyze issues related to the project participants and system architecture design. A system architecture of a management system is proposed for buried objects under roads to be visualized in a 3D model. The system manages maintenance information and can be used by road administrators and construction engineers. The proposed system has a data model framework capable of maintaining buried objects under roads and road asset management.

USE OF THREE-DIMENSIONAL DATA

In Japan, the Ministry of Land, Infrastructure, Transport and Tourism has been promoting Construction Information Modeling (CIM) and i-Construction, which advocate the development of environments for use of 3D information. Use of 3D information is difficult in local governments, however, as a result of budget constraints, insufficient technical skills, and human resource shortages.

There are many cases where ledgers lack accurate information on the location of buried objects under roads. Therefore, pipes for gas, electric power, water, and sewerage may be poorly represented in the ledgers, preventing construction engineers from laying pipes as designed during maintenance and repair. This can lengthen construction periods or cause accidents, adversely affecting road structure and traffic. During maintenance, buried objects under roads should be represented and managed using 3D geometry and attribute information, and all the objects must be accurately represented in ledgers. This is particularly true today because of the increased convergence of buried objects in urban areas.

METHODS

SSM was adopted to analyze issues regarding project participants and to design the system architecture. SSM has the objective of constructing a view of project participants and stakeholders and considering the direction and principles of the project. There are many government participants in these projects, including local government officers and representatives, road agencies, and contractors. SSM allows recognition and discussion of the associated problems. SSM consists of six elements: a process model, rich pictures, fundamental definitions, CATWOE analysis, the XYZ formula, and a conceptual model. This study focuses on the use of rich pictures, CATWOE analysis, and the conceptual model.

PRESENT PROBLEMS

Results of Rich Picture Analysis

Policy issues and research topics related to the use of 3D information during the civil infrastructure lifecycle (Kubota, 2012) include the establishment of standards for exchanging 3D Information, specifications for producing 3D information, construction of 3D product data models, definition of attribute information, construction of business process models, and development and evaluation of 3D CAD engines, 3D CAD software, and 3D viewers. In this study, SSM “rich pictures” like the one shown in Figure 1 represent the relations among project participants and stakeholders and organize unstructured problems. Figure 1 shows problems such as “lack of budget for using 3D data,” “engineers cannot understand the merits of using 3D data,” and “lack of human resources for use of 3D data.” It is necessary for construction and maintenance engineers to understand and utilize 3D information to reduce the duration of construction projects and to improve quality.

CATWOE Analysis

CATWOE analysis describes elements of the system architecture used to visualize buried objects under roads as 3D data, and manages the attributes of road maintenance information. Figure 2 shows a CATWOE analysis for applying 3D information to the maintenance of buried objects under roads. CATWOE prompts thinking about what the project is trying to achieve. It determines a “transformation process” based on a “world view” and translates inputs to outputs. “Actors” conduct the process, “customers” receive the resulting output, and “owners” control the transformation process. The mechanism also has “environmental constraints.”

C (Customers): Who are the beneficiaries of the highest-level business process, and how does the issue affect them?

A (Actors): Who is involved in the situation, who will be involved in implementing solutions and what will impact their success?

T (Transformation process): What is the transformation that lies at the heart of the system?

W (World view): What is the big picture and what are the wider impacts of the issue?

O (Owner): Who owns the process or situation being investigated and what role will they play in the solution?

E (Environmental constraints): What are the constraints and limitations that will impact the solution and its success?



Figure 1: Rich Picture for Problems Related to 3D Data Use in Local Government

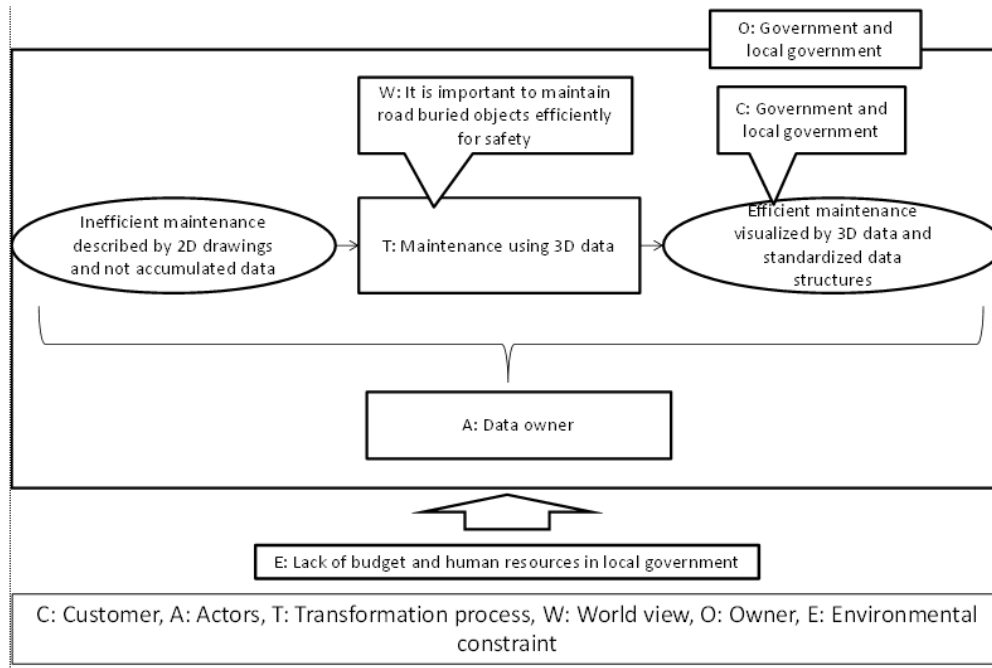


Figure 2: Catwoe

SYSTEM PROPOSAL

Use Case of the System

A management system for buried objects under roads is proposed that visualizes them using 3D data and manages maintenance attributes. The system targets buried objects under roads in congested urban areas. Figure 3 shows a use case based on Unified Modeling Language (UML) for the system. In the maintenance stage, 3D data produced through planning, design, and construction are used. In the planning and design stages, engineers can more accurately create simulation data and completion images. In the construction stage, engineers can better understand relations between underground locations, thereby reducing the number of related construction accidents. There are few examples of local governments using common information models for 3D representation of buried objects. Implementation of the proposed system can therefore be expected to increase 3D data use in local governments.

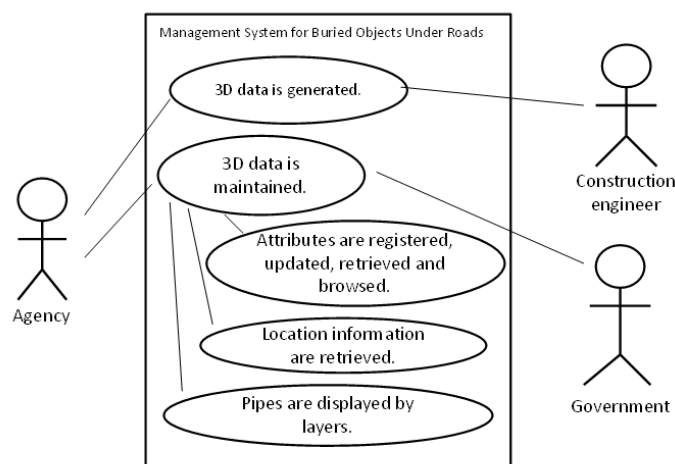


Figure 3: System Use Case

System Architecture

Figure 4 shows a conceptual model of the system based on the construction process of buried objects under roads. It is impossible to convert the two-dimensional (2D) data for existing buried objects to 3D data. Existing data are therefore updated to 3D data when buried objects are newly constructed and updated by construction engineers. In this system, the buried objects are displayed on a 2D map and as 3D data on the screen. Local government officers and contractors can browse the data on the Internet. The proposed system also manages the 3D data and attributes that were included in the 2D of papers in the past. Figure 5 shows 3D data on sewerage pipe, taken from the web page of the Tokyo Metropolitan Government Bureau of Sewerage. It shows that 3D data enables visualization of the complicated situation of buried objects and allows browsing and modifying the attributes.

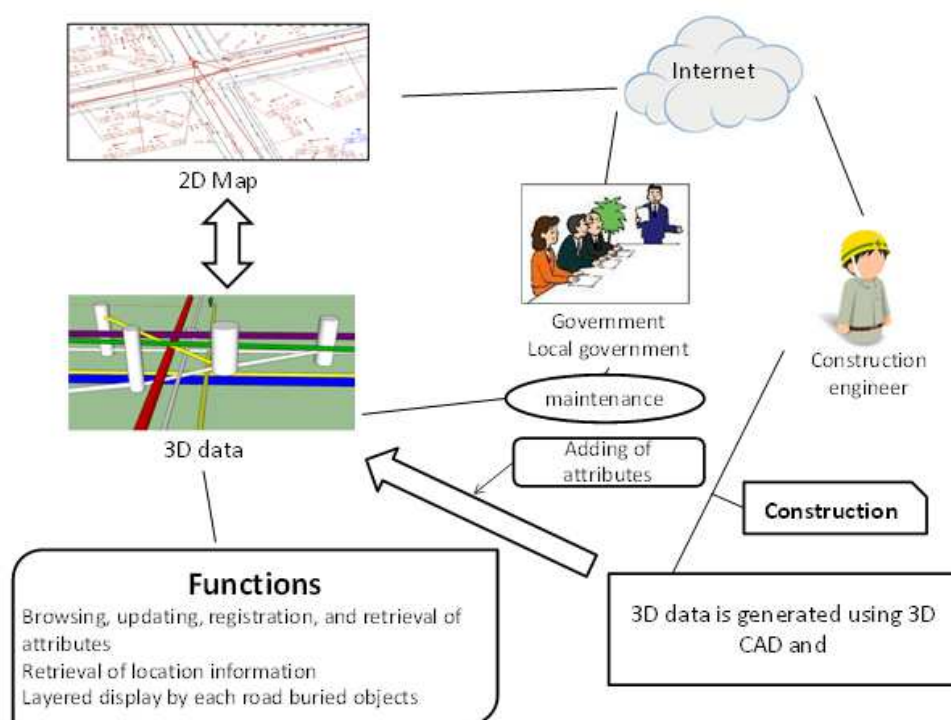


Figure 4: Conceptual Model of the System

Data Model of Buried Objects

The data structure for buried objects under roads are defined and standardized in the proposed system. Figure 6 shows the data structure definitions. The UML class diagram describes buried objects for which decreased functionality will affect citizens, based on management data product specifications in the road ledger (Ministry of Land, Infrastructure, Transportation and Tourism, 2005). Included are data structures for water, sewerage, gas, electric power, and communication pipes, and common ducts, describing their length, construction material, final completion date, type of construction, location information, and geometric shape. It also describes the depth, data acquisition date, data creator name, manager name, owning agency name, final completion date, type of construction, location information, and geometric shape of other underground structures. These attributes are accumulated based on the definitions in Figure 6.

CONCLUSIONS

This study targeted maintenance of buried objects under roads by local government as a use case of 3D data. SSM was adopted to analyze issues related to project participants and to design the system architecture. CATWOE analysis identified elements for constructing a 3D management system. A system architecture of a management system for buried objects under roads was proposed. UML was used to define a data model that described buried objects and underground structures in detail, including location and depth, creation date, data creator, local government name, owning company, and geometry data for water, sewerage, and gas pipes. The data model framework in the proposed system is capable of describing buried objects for road asset maintenance and management using 3D models.

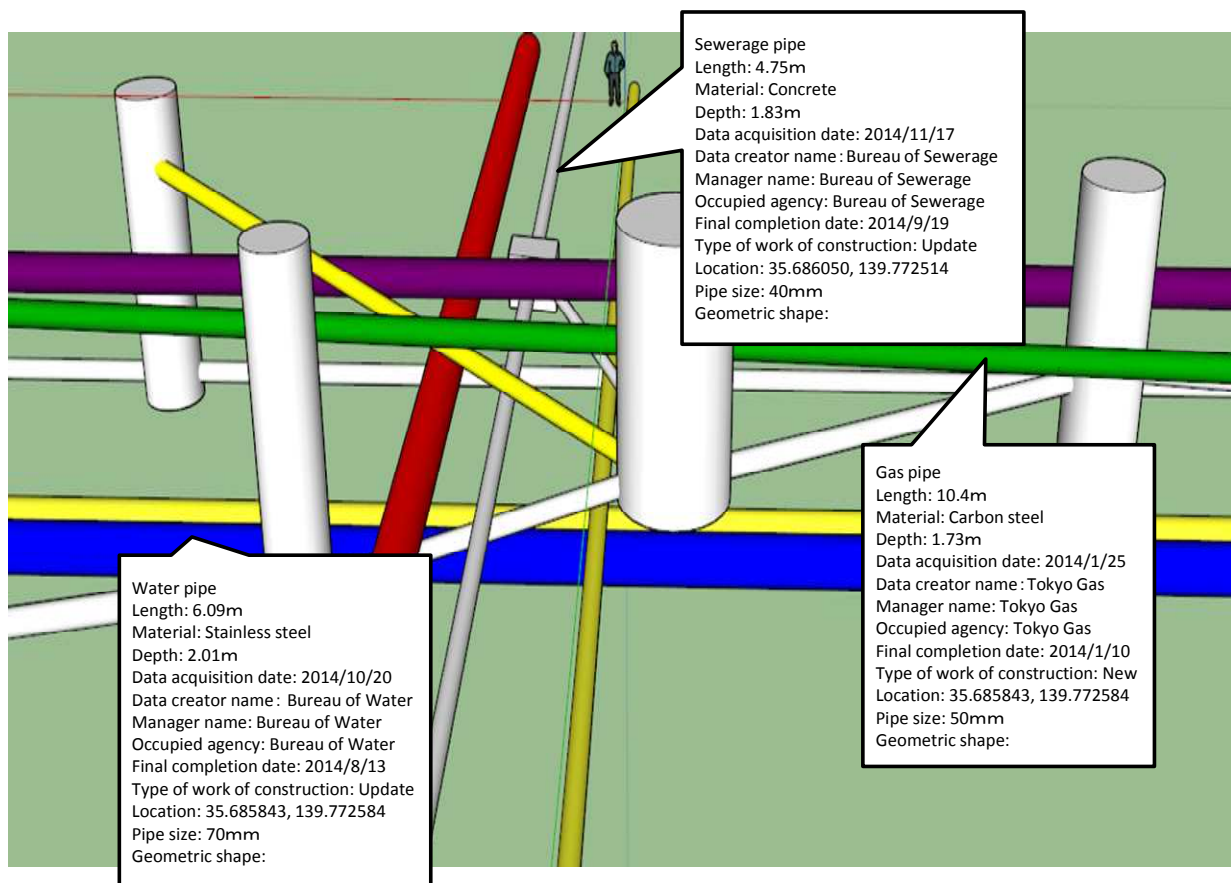


Figure 5: 3D sewerage pipe

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APPENDICES

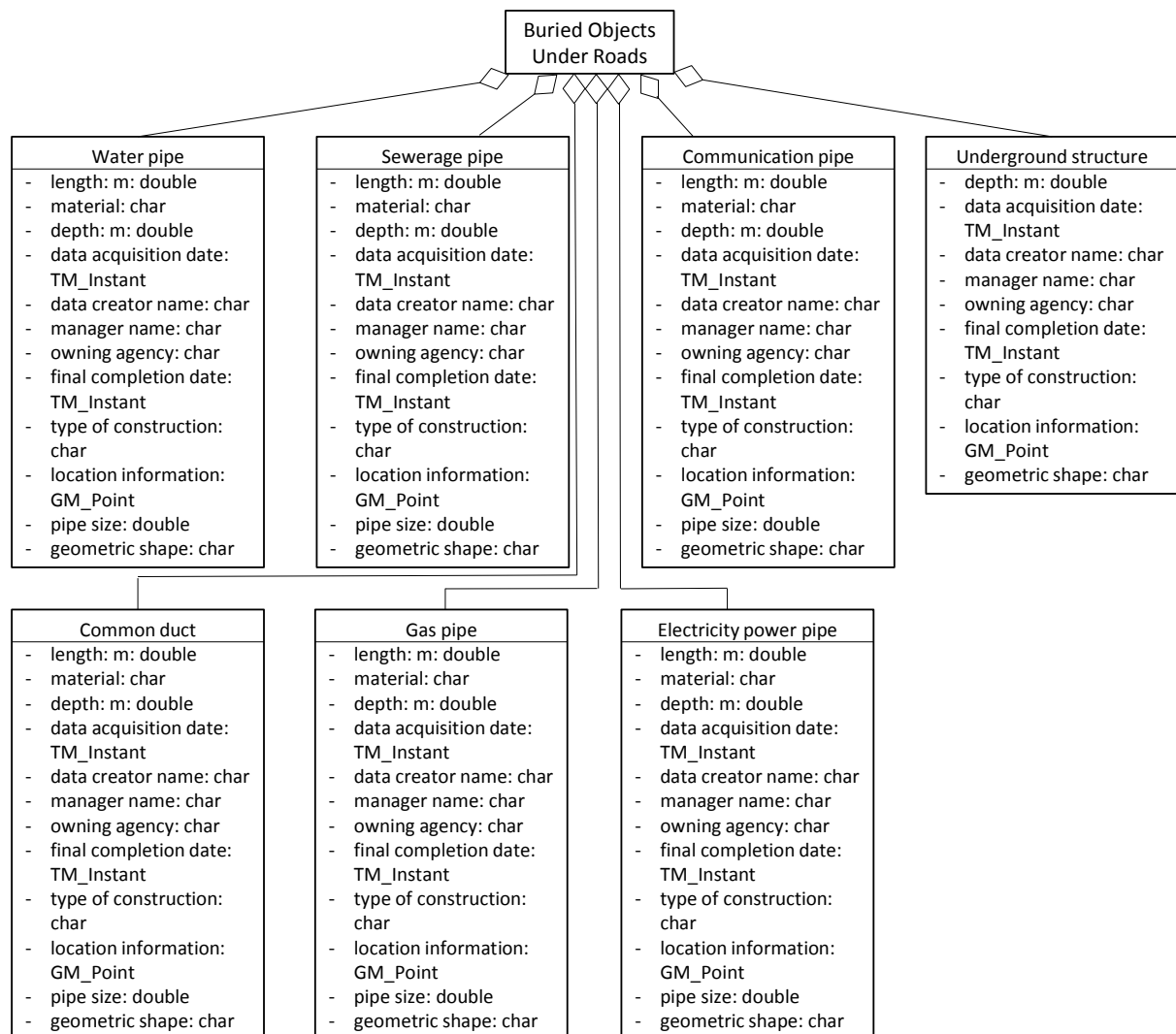


Figure 6: Data Structure for Buried Objects Under Roads

